STRONTIUM

By Joyce A. Ober

Domestic survey data and tables were prepared by Hoa P. Phamdang, statistical assistant, and the world production table was prepared by Regina R. Coleman, international data coordinator.

Domestic strontium consumption continued to decrease because its major end use, color television faceplate glass production, was declining in the United States owing to the shift of production to Asia and increased popularity of new flat panel television displays that do not use strontium carbonate in their glass. Worldwide, strontium ore production increased as a result of significantly expanded production in China and Mexico.

Late in the year, Chemical Products Corp. (CPC) of Cartersville, GA, which was the only U.S. producer of strontium compounds from celestite, reached an agreement with Solvay S.A. of Belgium, which was the world's leading producer of strontium compounds, to form a joint venture for the production and marketing of barium and strontium carbonate. Aligning the two companies' operations in Germany, India, and the Republic of Korea will allow them to compete more efficiently in the changing markets, especially in Asia (Solvay S.A., 2004).

Strontium occurs commonly in nature; it averages 0.04% of the Earth's crust and is the 15th element in abundance (MacMillan and others, 1994). Only two minerals, celestite (strontium sulfate) and strontianite (strontium carbonate), however, contain strontium in sufficient quantities to make its recovery practical. Of the two, celestite occurs much more frequently in sedimentary deposits of sufficient size to make development of mining facilities attractive. Neither mineral is mined in the United States, although deposits have been identified and were mined in the past.

Legislation and Government Programs

In 2004, the National Defense Stockpile contained approximately 12,000 metric tons (t) of celestite, which was authorized by the U.S. Congress for disposal. No bids were made on the material that was offered for sale. Celestite has been offered for sale from the stockpile every year since 1994; none has been purchased. The low quality of the material that remains in the stockpile makes it undesirable as raw material for strontium carbonate production. Reports issued by the Defense National Stockpile Center of the Defense Logistics Agency, which is the agency now responsible for managing stockpile sales, list the celestite as valueless.

Production

CPC voluntarily provided domestic production and sales data to the U.S. Geological Survey (USGS). These data, however, have been withheld from publication to avoid disclosing company proprietary data (table 1). CPC was the only domestic company that produced strontium carbonate from celestite; the company also produced strontium nitrate. All the celestite that CPC used at its Cartersville plant in 2004 was imported from Mexico; CPC owned and operated a second strontium carbonate plant in Reynosa, Mexico.

Consumption

The USGS estimated the distribution of strontium compounds by end use. Of the six operations to which a survey request was sent, five responded. The information collected from this survey and the information provided by the U.S. Census Bureau on strontium trade were the bases for the end-use estimates listed in table 2.

In 2004, almost 80% of all strontium was consumed in ceramics and glass manufacture, primarily in television faceplate glass and secondarily in ceramic ferrite magnets and other ceramic and glass applications. Although consumption in television glass declined, it remained the predominant end use for strontium.

All color televisions and other devices that contain color cathode-ray tubes (CRTs) sold in the United States are required by law to contain strontium in the faceplate glass of the picture tube to block x-ray emissions. Major manufacturers of television picture tube glass incorporate, by weight, about 8% strontium oxide in their glass faceplate material. Added to the glass melt in the form of strontium carbonate, strontium is converted to strontium oxide. In addition to blocking x rays, strontium improves the appearance of the glass and the quality of the picture and increases the brilliance (Wagner, 1986). Domestic television glass production has begun a steep decline with the closure of one plant in 2003 and the closure of three in 2004. At the end of 2004, only one plant in Pennsylvania produced television glass.

Permanent ceramic magnets are another end use for strontium compounds in the form of strontium ferrite. These magnets are used extensively in small direct-current motors for automobile windshield wipers, loudspeakers, magnetically attached decorative items, toys, and other electronic equipment. Strontium ferrite magnets have high coercive force and high thermal and electrical resistivities and are chemically inert. They retain their magnetism well, are not adversely affected by electrical currents or high temperatures, do not react with most chemical solvents, and have a low density (Haberberger, 1971).

One of the most consistent and continuing applications for strontium is in pyrotechnic devices. Strontium burns with a brilliant red flame, and no other material is known to perform better in this application. The compound used most frequently in these devices is strontium nitrate, although strontium carbonate, strontium chlorate, strontium oxalate, and strontium sulfate could also be used. Pyrotechnic devices are used in military and nonmilitary applications. Military pyrotechnic applications include marine distress signals, military flares, and tracer ammunition. Nonmilitary applications include fireworks and warning devices (Conkling, 1981).

Strontium can be used to remove lead impurities during the electrolytic production of zinc. The addition of strontium carbonate dissolved in sulfuric acid reduces the lead content of the electrolyte and of the zinc deposited on the cathode (Bratt and Smith, 1963).

Strontium chromate is used as an additive to corrosion-resistant paint to coat aluminum, most notably on aircraft fuselages and ships, effectively. These paints are used, to some degree, on aluminum packaging to prevent corrosion (Roskill Information Services Ltd., 1992, p. 76).

Strontium metal was a very small part of total strontium consumption. Small amounts of strontium added to molten aluminum make it more suitable for casting such items as engine blocks and wheels. The addition of strontium to the melt also improves the machinability of the casting. The use of cast aluminum parts instead of steel has become common in the automotive industry because of the reduced weight and improved gas mileage (Lidman, 1984).

Other end uses consumed only small amounts of strontium and strontium compounds. As mentioned earlier, the presence of strontium in glass applications improves the brilliance of the glass. It also improves the quality of certain ceramic glazes and eliminates the toxicity that may be present in glazes that contain barium or lead. Strontium titanate is sometimes used as a substrate material for semiconductors and in some optical and piezoelectric applications. Strontium chloride is used in toothpaste for temperature-sensitive teeth. For this application, impurities must be strictly controlled; some limits are in the part-per-million range. Strontium phosphate is used in the manufacture of fluorescent lights, and the entire range of strontium chemicals is used in analytical chemistry laboratories.

Prices

According to data published by the U.S. Census Bureau, the average customs value for celestite imported from Mexico was about $53 per metric ton, which was 7.4% lower than that of 2003. The average unit customs value of imported strontium carbonate was $0.35 per kilogram, which was a decrease of 25% from $0.48 in 2003. In 2004, the corresponding value for strontium nitrate was $1.52 per kilogram, which was a 48% decrease from $2.95 per kilogram in 2003.

Foreign Trade

Exports of strontium compounds decreased by 19% from those of 2003 (tables 1, 3). Imports of celestite from Mexico were 6,290 t, which was nearly 2.8 times more than they were the previous year, but still very low from a historical perspective.

Mexico continued to be the most important source for imported strontium compounds with almost 90% of the total, followed by Germany with 7% (table 4). In 2004, imports of strontium carbonate were 38% lower than those of 2003. Imports from Mexico were 94% of total strontium carbonate imports. Imports of strontium nitrate, which was the second leading imported strontium compound, varied significantly from year to year but typically represent about 2% of total strontium imports. In 2004, imports of strontium nitrate were 25% lower than those of 2003.

World Review

In most instances, celestite deposits occur in remote undeveloped locations far from population centers and in areas where inexpensive labor is available for mining. Huge deposits of high-grade celestite have been discovered throughout the world. Strontium commonly occurs along with barium and calcium, which have chemical properties very similar to strontium, thus making separation difficult. Because removing many impurities from celestite is difficult and energy-intensive, strontium chemical producers require that raw materials contain at least 90% strontium sulfate. Most operating celestite facilities produce sufficient supplies with only minimal processing necessary to achieve acceptable specifications. Hand sorting and some washing are all that are necessary at many strontium mines; a few operations use froth flotation, gravity separation, or other methods to beneficiate ore.

The leading celestite producing countries were, in decreasing order of output, Mexico, Spain, and China, all with more than 100,000 t of production in 2004. Turkey was another leading celestite producer. Significant quantities of celestite were believed to have been produced in Tajikistan, but not enough information was available to make an estimate on the level of production. Celestite was produced in smaller quantities in Argentina, Iran, Morocco, and Pakistan (table 5). Production facilities for strontium compounds and metal were located in Canada, China, Germany, Japan, the Republic of Korea, Mexico, and the United States.

Detailed information on most world resources was not readily available because very little information on exploration results has been published. Other deposits may be well identified but are in countries from which specific minerals information was not easily obtained.

China.—A long-time supplier of celestite and strontium carbonate, China was the world's leading producer of strontium carbonate with a capacity of more than 200,000 metric tons per year (t/yr) in 2003. Most of its output was exported. Because celestite production was insufficient to meet domestic demand, China imported celestite from Spain to supply its strontium carbonate plants (Coope, 2003).

To expand the ability to meet celestite demand internally, China constructed a 300,000-t/yr celestite concentrate plant at the Qaidam Basin in Qinghai Province. A 30,000-t/yr strontium carbonate plant was built adjacent to the celestite operation with plans to double

capacity in future development projects. The Qaidam Basin was reported to contain 80% of proven celestite reserves in China (People's Daily Online, 2004§[1]).

Spain.—Celestite was mined at two locations in Spain, thus making it one of the leading producers of celestite in the world second only to Mexico. The Montevive deposit was mined by Canteras Industriales S.L., and the Escuzar deposit was mined by Solvay Minerales S.A. (a subsidiary of Solvay). The Montevive deposit contains 8 million metric tons (Mt) of estimated reserves, and reserves at Escuzar are estimated to be 4 Mt (Regueiro, 2004).

Quimica del Estroncio, S.A. (a joint venture of Minas de Almadadén y Arrayanes, S.A., Fertiberia S.A., Solvay, and Ercros Industrial S.A.) operated a 35,000-t/yr strontium carbonate and 6,000-t/yr strontium nitrate plant in Cartegena. The plant used an unusual technology for strontium carbonate production; strontium nitrate was produced in an intermediate step in the process (Quimica del Estroncio, S.A., undated§).

Outlook

Shifts have begun in sales of televisions and computer monitors in the United States. Although many televisions sold still contain CRTs, flat panel technology that requires little or no strontium is quickly gaining market share as the market prices decrease faster than had been anticipated. In addition, market economics have shifted the production of faceplate glass for smaller televisions to Asia and Mexico where increasing numbers are being built for sale in the United States. These changes have resulted in decreased domestic strontium carbonate production and the likelihood that decreases might be even more dramatic in the next few years.

Because three of the four television faceplate glass plants closed in 2004, strontium demand for this end use can be expected to drop dramatically in 2005 and will likely remain low. Television glass production also has declined in Europe. Strontium demand for CRTs should continue in Asia and Mexico, but newer television technology could possibly replace CRTs in those markets as well.

Ferrite magnet markets are expected to be strong, and demand for strontium is likely to continue. Growth in other markets will probably continue at the current slower rate. Improved economic conditions worldwide could spur growth in demand for strontium carbonate applications.

References Cited

Bratt, G.C., and Smith, W.N., 1963, The effects of strontium compounds and related materials in the electrolytic production of zinc, *in* Australian Conference on Electrochemistry, 1st, Sydney, Australia, February 13-15, 1963, Proceedings: New York, NY, Pergamon Press, p. 939-948.

Conkling, J.A., 1981, Chemistry of fireworks: Chemical and Engineering News, v. 59, no. 26, June 29, p. 24-32.

Coope, Brian, 2003, Celestite sales east: Industrial Minerals, no. 428, May, p. 46-49.

Haberberger, T.H., 1971, Ferrite applications ever changing and expanding: Ceramic Industry Magazine, v. 115, no.8, August, p. 29-32.

Lidman, W.G., 1984, Master alloys improve aluminum casting properties: Foundry Management and Technology, v. 112, no. 8, August, p. 46-47.

MacMillan, J.P., Park, J.W., Gerstenberg, Rolf, Wagner, Heinz, Köhler, Karl, and Wallbrecht, Peter, 1994, Strontium compounds and chemicals, *in* Ullman's encyclopedia of industrial chemistry (5th ed.): Weinheim, Germany, VCH Verlagsgesellschaft mbH, v. A25, p. 321-327.

Reguiero, Manuel, 2004, Spain's industrial minerals—A wealth of opportunity: Industrial Minerals, no. 441, June, p. 28-41.

Roskill Information Services Ltd., 1992, The economics of strontium: London, United Kingdom, Roskill Information Services Ltd., 93 p.

Solvay S.A., 2004, Solvay and Chemical Products Corporation seek to create global barium strontium joint venture: Brussels, Belgium, Solvay S.A. press release, November 24, 2 p.

Wagner, R.G., 1986, Glass as a CRT fabrication material: Glass, v. 63, no. 6, June, p. 191-192.

Internet References Cited

People's Daily Online, 2004 (June 10), China's largest celestite concentration plant, strontium carbonate base built, accessed May 4, 2005, at URL http://english.people.com.cn/200406/30/eng20040630_148076.html.

Quimica del Estrontio, S.A., [undated], An initiative for the future, accessed October 10, 2004, at URL http://www.qsrestroncio.com/pages/english/01.html.

GENERAL SOURCES OF INFORMATION

U.S. Geological Survey Publications

Evaporites and Brines. Ch. in United States Mineral Resources, Professional Paper 820, 1973.
Strontium. Ch. in Mineral Commodity Summaries, annual.

Other

American Ceramic Society Bulletin, monthly.
Chemical Market Reporter, weekly.
Engineering and Mining Journal, monthly.
Industrial Minerals, monthly.
Mining Annual Review.
Mining Engineering, monthly.

[1]References that include a section mark (§) are found in the Internet References Cited section.

Mining Journal, weekly.
Roskill Information Service Ltd. [last reported on strontium in 1995].
Strontium—Supply, Demand, and Technology. U.S. Bureau of Mines Information Circular 9213, 1989.
Strontium. Ch. in Mineral Facts and Problems, U.S. Bureau of Mines Bulletin 675, 1985.

TABLE 1
SALIENT STRONTIUM STATISTICS[1]

(Metric tons of contained strontium and dollars per metric ton unless otherwise noted)[2]

	2000	2001	2002	2003	2004
United States:					
Production, strontium minerals	--	--	--	--	--
Imports for consumption:[3]					
Strontium compounds	29,900	26,500	25,400	23,300	14,500
Strontium minerals	7,460	5,640	1,150	1,020	2,760
Exports, compounds[3]	4,520	929	340	693	552
Shipments from Government stockpile excesses	--	--	--	--	--
Apparent consumption[4]	32,800	31,200	26,200 r	23,600	16,700
Price, average value of mineral imports at port of exportation	62	63	60	57 r	53
World production of celestite[5]	396,000 r	398,000 r	435,000 r	470,000 r	551,000 e

eEstimated. rRevised. -- Zero.

[1]Data are rounded to no more than three significant digits.

[2]The strontium content of celestite is 43.88%, which was used to convert units to celestite.

[3]Source: U.S. Census Bureau.

[4]Production plus imports minus exports.

[5]Excludes Tajikistan, which was believed to produce significant quantities of celestite, but information was not available to make reliable estimates.

TABLE 2
U.S. ESTIMATED DISTRIBUTION OF PRIMARY
STRONTIUM COMPOUNDS, BY END USE

(Percent)

End use	2003	2004
Electrolytic production of zinc	2	2
Ferrite ceramic magnets	10	11
Pigments and fillers	2	2
Pyrotechnics and signals	10	14
Television picture tubes	73	68
Other	3	3
Total	100	100

TABLE 3
U.S. EXPORTS OF STRONTIUM COMPOUNDS, BY COUNTRY[1]

	2003		2004	
	Gross weight (kilograms)	Value[2]	Gross weight (kilograms)	Value[2]
Strontium carbonate, precipitated:				
Canada	42,600	$39,600	36,900	$27,600
Germany	32,000	130,000	9,930	40,200
Hong Kong	35,100	50,600	45,600	43,400
Japan	12,300	12,600	55,400	31,100
Korea, Republic of	171,000	62,800	5,000	4,750
Malaysia	--	--	80,000	32,000
Mexico	60,500	57,500	108,000	46,600
United Kingdom	18,600	96,300	14,700	36,100
Other	2,580	3,040	4,190	3,980
Total	375,000	452,000	360,000	266,000
Strontium oxide, hydroxide, peroxide:				
Australia	--	--	27,200	14,900
Belgium	--	--	57,600	37,500
Brazil	6,910	20,000	12,600	6,930
Canada	50,500	26,200	67,200	34,400
Germany	35,400	19,500	--	--
Japan	--	--	56,200	220,000
Korea, Republic of	--	--	146,000	80,400
Mexico	523,000	287,000	28,400	43,000
Netherlands	29,200	16,100	--	--
Thailand	8,410	4,630	10,800	5,940
United Kingdom	--	--	29,400	16,200
Other	--	--	33,400	18,400
Total	653,000	374,000	469,000	477,000

-- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Free alongside ship value.

Source: U.S. Census Bureau.

TABLE 4

U.S. IMPORTS FOR CONSUMPTION OF STRONTIUM COMPOUNDS, BY COUNTRY[1]

	2003		2004	
	Gross weight (kilograms)	Value[2]	Gross weight (kilograms)	Value[2]
Celestite, Mexico	2,320,000 r	$132,000 r	6,290,000	$332,000
Strontium carbonate:				
Belgium	61,800	26,100	161,000	63,800
China	114,000	45,000	77,000	30,000
Germany	2,060,000	900,000	1,680,000	723,000
Italy	1,000	6,620	2,000	8,720
Mexico	35,800,000	17,200,000	21,700,000	7,580,000
Netherlands	20,600	8,170	--	--
Spain	200,000	85,300	--	--
United Kingdom	20	5,390	11,000	22,200
Total	38,200,000	18,200,000	23,600,000	8,430,000
Strontium metal:				
Canada	39,900	263,000	10,400	74,300
China	15,000	72,300	42,800	205,000
France	10,000	67,700	18,000	121,000
Japan	218,000	682,000	144,000	667,000
Korea, Republic of	--	--	1,840	2,840
United Kingdom	300	2,570	--	--
Total	283,000	1,090,000	217,000	1,070,000
Strontium nitrate:				
China	375,000	261,000	226,000	204,000
Japan	252,000	1,750,000	69,200	426,000
Mexico	77,100	56,300	231,000	169,000
Other	30 r	9,460 r	--	--
Total	705,000	2,080,000	527,000	798,000
Strontium oxide, hydroxide, peroxide:				
China	--	--	83,000	52,900
Japan	--	--	15,000	22,700
Total	--	--	98,000	75,600

rRevised. -- Zero.

[1]Data rounded to no more than three significant digits; may not add to totals shown.

[2]Free alongside ship value.

Source: U.S. Census Bureau.

TABLE 5
CELESTITE: WORLD PRODUCTION, BY COUNTRY[1, 2]

(Metric tons)

Country[3]	2000	2001	2002	2003	2004[e]
Argentina	4,656	2,440	3,106	3,323	3,400
China[e]	50,000	50,000	100,000	100,000	130,000
Iran[e, 4]	2,000	2,000	2,000	2,000	2,000
Mexico	157,420	145,789	94,015	130,329 [r]	181,300 [p]
Morocco	7,539	1,879	3,780	2,700 [e]	2,700
Pakistan[e]	1,918 [5]	2,000	2,000	2,000	2,000
Spain	148,352	129,794	160,519	160,000 [e]	160,000
Turkey	24,150	63,635	70,000 [e]	70,000 [e]	70,000
Total	396,000 [r]	398,000 [r]	435,000 [r]	470,000 [r]	551,000

[e]Estimated. [p]Preliminary. [r]Revised.

[1]World totals and estimated data are rounded to no more than three significant digits; may not add to totals shown.

[2]Table includes data available through May 20, 2005.

[3]In addition to the countries listed, Tajikistan was believed to produce celestite, but information was not available to make reliable estimates.

[4]Data are for year beginning March 21 of that stated.

[5]Reported figure.